CHAPTER 9: RIGHT OF WAY CHANGE: CHANGE AND CLEARANCE INTERVALS

This chapter includes information that you will need to prepare for, conduct, and assess each of the seven activities included in Chapter 9 of the student activity book Figure 1 shows the various files that are available to support your works as you use these activities, including mini-lecture slides, solution files, and student resource files.

Chapter 9 Right of Way Change	Mini-lecture slides	Solution files	Student resource files
A#52 Reading			
A#53 Assessment			
A#54 Discovery			
A#55 Field			
A#56 Design			
A#57 In Practice			

Figure 1. Support files

Figure 2 shows the kind of work required for each activity, how the activities might be grouped, and the approximate amount of class time required to complete the activity. The figure also identifies whether there is homework involved, a mini-lecture could be presented, student discussion could take place, and group work to do.

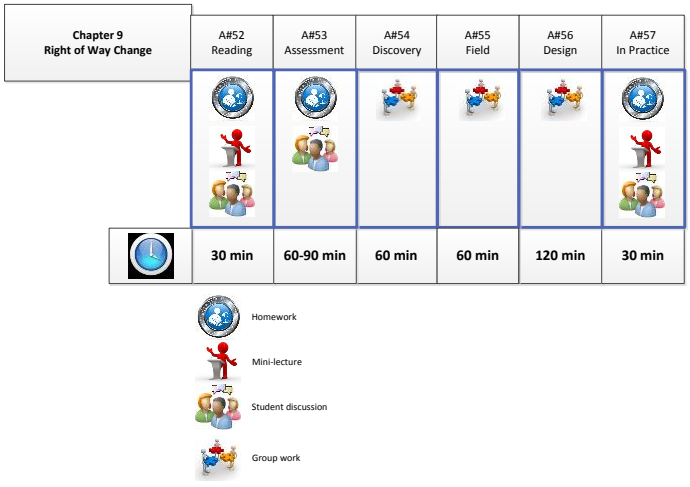


Figure 2. Activity work

Using Activity #52: The Theoretical Basis of the Yellow and Red Clearance Timing Intervals (Reading)

Overview

This activity presents the theoretical basis for setting the yellow and red clearance intervals.

Options for Use

The reading, defining the terms in the glossary, and answering the critical thinking questions are usually done as homework, to prepare for class discussion. After the students complete this work, the instructor has several options for assessing and clarifying student understanding of the reading during class:

- Quiz to assess their understanding and to hold them accountable for the reading.
- Present mini-lecture summarizing key points from the reading, with active questioning of the students as the lecture material is presented.
- Discussion and synthesis of the answers to the quiz, the glossary definitions, and answers to the critical thinking questions.

Preparing for the Activity

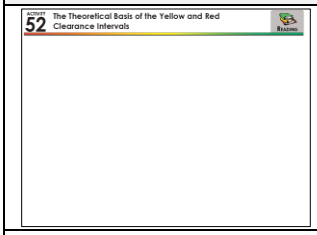
- Decide which of the options you want to do during class.
- Prepare for class by reviewing Activity #52, including the "Information", the Glossary definitions, and the Critical Thinking Questions and answers

The reading describes the theoretical approach to setting the yellow and all-red timing intervals, an approach that is recommended by the Institute of Transportation Engineers. However, there are a number of concerns that some engineers in practice have expressed about the equation derived from this approach. These concerns include the variability in driver response to yellow as well as the variability of approach speeds: both factors undermine the seeming certain of the calculation method described in the reading.

Doing the Activity (Script)

[Slides: slides52.pptx]

The following script can be used along with the PowerPoint slides for this activity. The script and slides can be modified based on your needs and what you decide to emphasize.

Slide	Text
	
	The ring barrier diagram provides a means to define which phases can time concurrently and which must be timed sequentially. Safety requires a time separation between the phases that must be timed

Slide	Text
	sequentially. This time interval we can the change period, and it consists of the change interval and the clearance interval. The theory behind setting these intervals requires us to consider the following factors: 1. How long it takes a driver to perceive the need to stop and then to actually brake to a stop. 2. How long it takes a driver to safely and completely clear the intersection.
	But as we will see, this theory makes some assumptions about a constant arrival speed of all vehicles, a uniform vehicle length, and a homogeneous response of all drivers. None of these are true. So we will first develop a theory and then we will look at how the variability in these parameters complicates the selection of the yellow and red clearance intervals. And, we will also consider the effects on driver behavior (response) when we try to increase or decrease the yellow (particularly increase) duration. So, let's begin our journey through the intersection!
	We'll consider one of the intersections along Lankershim Blvd in Los Angeles. Earlier you took a video tour of this arterial and used some of the high resolution data that had been collected in your study of vehicle trajectories and time-space diagrams. So here is the intersection of Lankershim Blvd with Campo de Cahuenga and Universal Hollywood Drive. You can see from this diagram that the width of the intersection is 115 feet and that we can see up to 330 feet upstream of the stop bar. [Here is the view that you have of the intersection from that point of 330 feet upstream.]
[sketch]	Let's start with some given data. L = 20 feet Delta = 1 second a = -10 feet/sec/sec v = 25 miles/hour or 36.75 ft/sec
	The first question to ask is: for a normal response to yellow, how far does a vehicle travel in stopping (reacting plus braking)? $x_s = \frac{v^2}{2a} = (36.75)(1) + \frac{36.75^2}{2(10)} = 36.75 + 67.53 = 104.28\ feet$
[sketch]	What do we know about this point? If the yellow indication appears when a driver is 104.28 feet upstream of the stop bar, the driver can safely stop. -->Closer? Can't stop. -->Farther? Can stop
[sketch]	The next question to ask: suppose instead of stopping from this choice

Slide	Text
	point, the driver decided to continue on through the intersection? How long would it take to clear the intersection from this point? $$x_c = x_s = 104.28 + 115 + 20 = 239.28\ feet$$ $$t_c = \frac{x_s + w + L}{v} = \frac{239.28}{36.75} = 6.51\ sec$$ This means that Y + RC = 6.51 seconds for a driver to observe yellow, decide to clear, and complete the clearance of the intersection.
	In theory, we want to divide the 6.51 sec into two components: 1. Get the driver from the choice point to the stop bar in Y 2. Travel from the stop bar (just entering the intersection) to rear of vehicle clearing the far side of the intersection in RC $$Y = \frac{x_s}{v} = \frac{104.28}{36.75} = 2.84\ sec$$ $$RC = \frac{w + L}{v} = \frac{135}{36.75} = 3.67\ sec$$
[sketch]	So if: v = 25 miles per hour w = 115 feet [other assumptions as above] 1. The choice point is 104.28 feet upstream of the stop bar. 2. Y+RC = 6.5 sec 3. Y = 2.8 sec 4. RC = 3.7 sec 5. If the Y+RC is too short (and drivers can't stop) then there is possibility of red light running and unsafe braking. 6. If the Y+RC is too long (drivers can either stop or clear), then there is possibility for disrespect of the Y and more rear end crashes.
	But what about our assumptions? In reality: • Driver speeds are distribution • Delta varies by driver • L varies (PCs and trucks) So what can we learn about driver behavior to help set Y? The issue is about probabilities and likelihoods. To help us with this, you will

Slide	Text
	compete two activities: • A54 which includes NGSIM data about driver response to yellow • A55 in which you will collect field data on driver responses to yellow

Solutions

Included here:

- Critical thinking questions and answers
- Glossary
- Variables

Critical Thinking Questions and Answers

1. What are the two factors that make up stopping distance?

- The two factors are the distance traveled while the driver perceives and reacts to the change in signal display and the distance traveled while the vehicle is decelerating.

2. What are the two conditions that must be true in order for a driver to be able to safely stop or safely clear the intersection when the yellow is first display?

- If the vehicle is closer to the intersection than the stopping sight distance, the yellow and all red time must be long enough for the driver to clear the intersection. If the vehicle is farther away from the intersection than the stopping sight distance, the driver will have time to stop at the intersection.

3. The value of t derived in the reading is the minimum value necessary to ensure that a driver will either be able to safely stop or safely clear the intersection when the yellow is displayed. What happens if the value is set higher than t just to provide an extra margin of safety? What would the trade-off be in this decision?

- If the value of t is set too high, vehicles which would have been able to safely travel through the intersection may stop, increasing delay. Additionally, drivers have an expectation of how long t should be. Increasing t would potentially cause drivers to become confused.

Glossary

- Dilemma zone - The area at an intersection approach, were the detector is located.
- Stopping distance - The distance which is needed for a vehicle to come to a full stop, this distance includes perception-reaction time
- Perception-reaction time - The time is takes for a driver to see and then react to an unknown traffic condition.
- Change interval - The yellow plus red clearance interval that occurs between phases of a traffic provide for clearance of the intersection before conflicting movements are signal to known as the clearance interval.
- Clearance interval - The time loss at a transit stop, not including passenger dwell times. This parameter can be the minimum time between one transit vehicle leaving a stop and the

following entering and can include any delay waiting for a sufficient gap in traffic to allow vehicle to reenter the travel lane.

Variables

- x_s – stopping distance
- v – vehicle speed
- δ – perception reaction time
- a – stopping acceleration
- w – width of the intersection
- L – vehicle length

Using Activity #53: What Do You Know About Change and Clearance Intervals? (Assessment)

Overview
This purpose of this activity is to have students understand the change and clearance intervals.

Options for Use
- This activity can be done either as homework or during class.

Preparing for the Activity
- Decide which of the options you want to do during class.
- Prepare for class by reviewing Activity #53.

Doing the Activity (Script)
Read through the activity and ask students to complete the tasks.

Solutions
[Excel file: solution53.xlsx]

Critical Thinking Questions and Answers
1. In addition to the values assumed in the example in the reading (v = 30 miles per hour, L = 20 feet, a = 10 feet per second per second) for passenger cars, what are the implications in setting the yellow and red clearance intervals if the traffic stream also included trucks with L = 58 feet and a = 6.4 feet per second per second? What values for these two timing intervals would you recommend and why?

2. Experience should tell you that there is likely to be a variation in the speeds of vehicles and the perception-reaction times of their drivers arriving on an intersection approach. Describe and complete a sensitivity analysis that you would perform to test the implications of variation in perception/reaction times and in actual approach speeds. What impact does this analysis have on your conclusions about the duration of the yellow and red clearance intervals?
- As reaction time increases, stopping sight distance and yellow plus all red time increases linearly. As speed increases, the stopping sight distance and yellow plus all red time initially decreases and then increases. The initial decrease was likely due to very low approach speeds. By doing these sensitivity analyses, it became clear that there will likely be great variation in each driver's decision to stop or go when the signal turns yellow because different drivers may have significantly different reaction times and approach speeds.

Using Activity #54: Drivers Responding to Yellow and Red Indications (Discovery)

Overview
Students learn about the variability in driver response to the onset of the yellow display and how this affects the determination of the yellow and all-red clearance intervals.

Options for Use
- This activity can be done either during class or as homework.

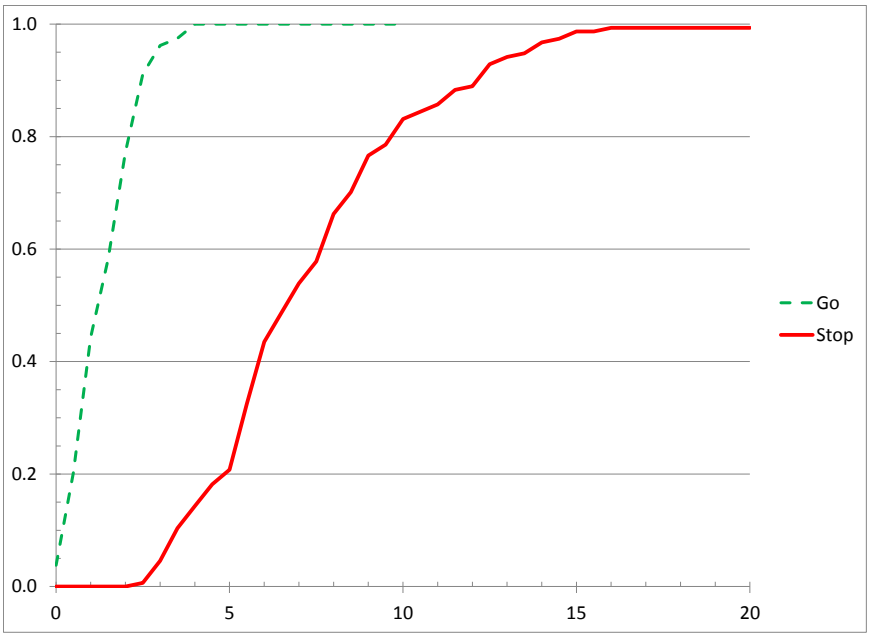
Preparing for the Activity
- Review the activity and the steps that the students will follow.

This activity presents students with 303 observations from the data set collected along Lankershim Blvd in Los Angeles as part of the Federal Highway Administration's NGSIM project. The data set was created by observing drivers at the time of yellow onset including their distance upstream of the stop bar, their speed, the time it would take for them to reach the stop bar based on their speed, and whether they stopped or continued through the intersection. This is the format for the data set, showing five observations each for vehicles that stopped and didn't stop.

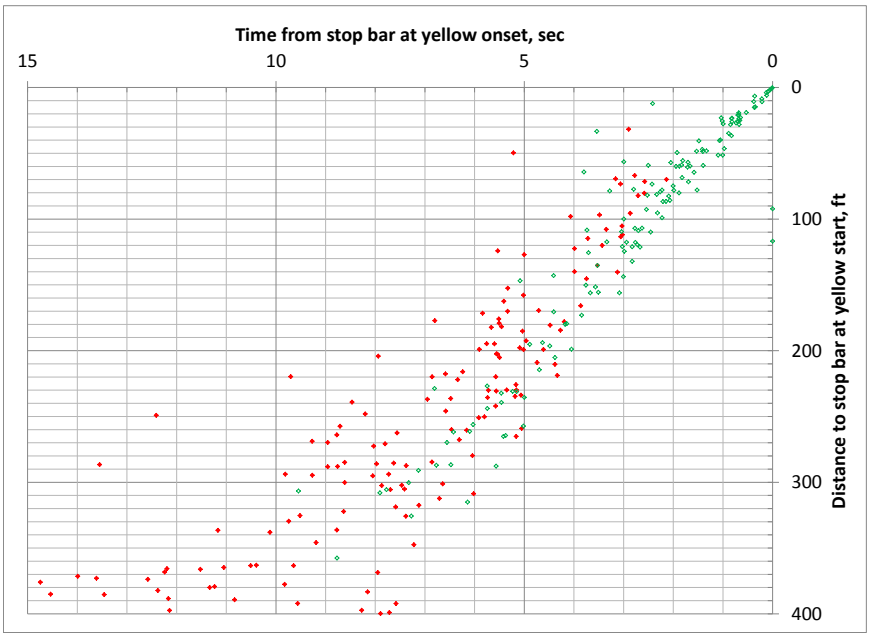
Distance2StopBar (ft)	Stop?	Speed (mi/hr)	TimeFromStopBar (sec)		Distance2StopBar (ft)	Stop?	Speed (mi/hr)	TimeFromStopBar (Sec)
-3.59	NO	15.5	-0.2		31.75	Yes	7.5	2.9
-3.46	NO	29.6	-0.1		49.77	Yes	6.5	5.2
-2.29	NO	31.5	0.0		66.91	Yes	16.4	2.8
-1.12	NO	22.0	0.0		69.41	Yes	15.0	3.2
-0.49	NO	25.1	0.0		69.92	Yes	22.3	2.1

The solution is discussed later, but it might be helpful to study the following figures before class so that you can develop a sense of some of the key relationships in the data.

The cumulative frequency diagrams of the time from the intersection stop bar at yellow onset (and whether or not the vehicles stopped or not) shows that 100 percent of the vehicles that four seconds or less from the stop bar did not stop, while 86 percent of the vehicles that were four seconds or more from the stop bar did stop. This is a pretty clear dividing line (you may argue for a different line) but it does illustrate that there is an overlapping time range in which some vehicles do stop and others don't.



Another chart shows the plot of “time from stop bar” vs. “distance to stop bar” at yellow onset and the same variability noted in the previous paragraph.



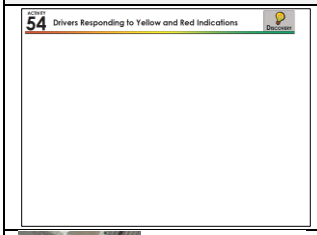
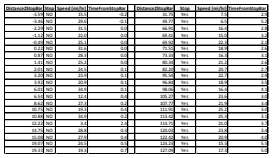
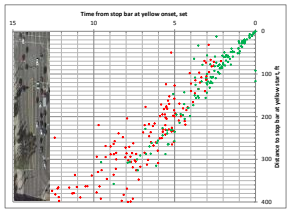
You might want to explore other aspects of this data set to deepen your understanding of its contents or identify other relationships that would be important for students to discover.

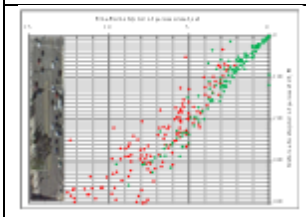
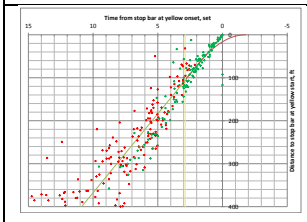
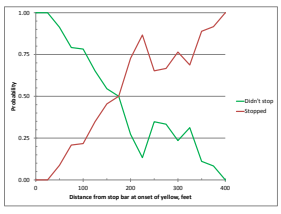
Hopefully, as a result of this activity, students will see the importance of considering the natural variability in the response of drivers in the field and how this variability affects design decisions such as setting the yellow and all-red intervals.

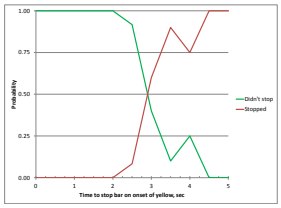
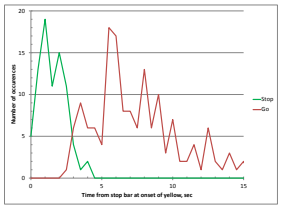
Doing the Activity (Script)

[Slides for conducting the activity: slides 54.pptx]

The following script can be used along with the PowerPoint slides for this activity. The script and slides can be modified based on your needs and what you decide to emphasize.

Slide	Text
	The purpose of this activity is to build your base of understanding of the change and clearance intervals. You will compare the theory behind the computation of the change and clearance intervals with how drivers actually behave in the field.
	We'll consider Lankershim Blvd in Los Angeles. You took a video tour of this arterial in Activity #2 and constructed time-space diagrams (vehicle trajectories) using data collected here as part of Activity #7. Here is the intersection of Lankershim Blvd with Campo de Cahuenga and Universal Hollywood Drive. You can see from this diagram that the width of the intersection is 115 feet and that we can see up to 330 feet upstream of the stop bar. On the right, you can see the view that you would have from that point of 330 feet upstream of the intersection.
	Here is what the data base looks like. • Distance to the stop bar when yellow onset • Whether the vehicle stops or not in response to yellow • Time to the stop bar at yellow onset
	Here is an example of one of the plots that you can construct with your data base. What does this plot show you? Example answers: • The closer to the intersection (in both time and distance), the more likely you are to proceed without stopping. • The farther away from the intersection, the more likely you are to stop. • There is a gray area, in which some drivers will stop and some drivers will proceed. [This makes it difficult to rely on one equation to estimate the yellow and all-red intervals. What are the implications of a yellow time that is not long enough: • Drivers can't stop so will either run the red light or will engage in unsafe braking. What are the implications of a yellow time that is too long:

Slide	Text
	• Drivers will develop disrespect for the yellow display and because of their variability of some drivers stopping and some not, there will likely be more rear-end collisions.
	[Review with the students the Purpose, the Learning Outcome, the Required Resources, and the Deliverable from Activity #54.] **Tell:** One of the most important aspects of this activity is to observe the variability of driver behavior, even when conditions (distance and/or time from stop bar) are the same.
	[Review the three tasks for this activity and write them on the board.] Task 1: Investigate the characteristics of the data set. Explain some of the ways that you can do this, through statistical summaries or frequency plots. The important point is to get to know the data set and what it can tell you. Task 2: Prepare a plot of the time and distance from the stop bar as illustrated previously. Task 3: How do your results from Task 2 compare with the theoretical basis for setting the change and clearance intervals?
	[Describe administrative details such as whether students should work in pairs or individually, when the activity is due, and what form it should be turned in (Excel spreadsheet, specific tabs, etc]
	Questions to ask: How does distance and/or time from stop bar affect decision to stop?
	[another slide showing chart yellow line]
	What is the likelihood of stopping affected by distance from stop bar?

Slide	Text
	What is the likelihood of stopping as it is affected by the time from stop bar?
	Another view of this distribution of stopping and going.

Solutions

The complete solution and data are included in a separate Excel file [solutions54.xlxs].

Using Activity #55: Vehicle Response to Displays at End of Green (Field)

Overview

In this activity, students will learn how drivers respond to yellow and red intervals in the field. The purpose of this activity is to allow students to observe how driver respond to change signal displays and allow them to describe this behavior.

Options for Use

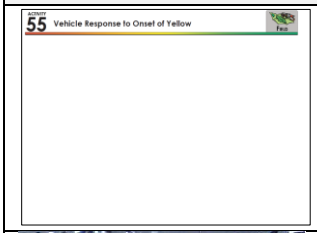
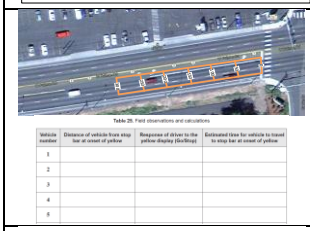
- This activity is done in the field.

Preparing for the Activity

- Review the activity and the steps that the students will follow.

Doing the Activity (Script)

[Slides: Slides55.pptx]
Review the activity with students before they begin their field work and use the following slides to illustrate the key points.

Slide	Text
	[Discuss the specifics of the activity.]
	Record where vehicles are when Y is displayed and whether they stop or not. • Make grid • Data to record
	Google Earth measuring tool.
	Summary after data collection in field: example of six vehicles, with their location upstream at yellow onset and whether they stopped or not.

Slide	Text
 	Data summary.

Solution

The following solution was created using the intersection of Palouse River Drive and Highway 95. Answers will vary greatly between students. Task 3 asks students to fill in Table 1.

Table 1. Field Work

Vehicle number	Distance of vehicle from stop bar at beginning of yellow	Response of driver to the yellow display	Distance of vehicle from stop bar at beginning of red	Assessment of driver behavior
1	20	Continued	-60	Safe
2	55	Continued	-40	Safe
3	65	Continued	-15	Safe
4	170	Stopped	70	Safe
5	90	Continued	-10	Safe
6	150	Continued	20	Unsafe
7	200	Stopped	110	Safe
8	210	Stopped	130	Safe
9	100	Continued	-5	Unsafe
10	80	Continued	-15	Safe

Using Activity #56: Determining the Vehicle Change and Clearance Intervals Considering Variability of Vehicle Approach Speeds (Design)

Overview

In this activity, students will select the vehicle change and clearance intervals for their design intersection. The purpose of this activity is to familiarize students with the concept of the dilemma zone and to have them select a vehicle change and clearance interval for their design project. There are several factors that contribute to the dilemma zone, the zone in which drivers must decide if they are going to proceed through an intersection once the light turns yellow or if they will come to a stop. These factors include the speed of the approach, the length of the intersection, and the driver's reaction time. This activity focuses specifically on the impacts that changes in approach speed has on the calculation of yellow and all red times; however, students should be encouraged to think about the other variables instead. This will help them to understand that while we typically use default values for these variables in design, that each driver will have slightly different variable values.

Options for Use

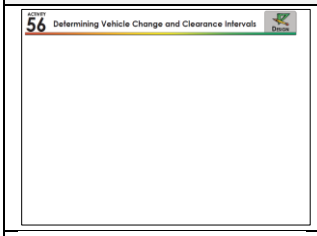
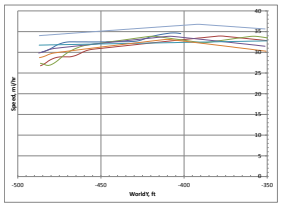
- This activity is normally done in the classroom.

Preparing for the Activity

- Review the activity and the steps that the students will follow.

Doing the Activity (Script)

[Slides: slides56.pptx]
Review the activity with students before they begin their work.

Slide	Text
	
	[Example plot of vehicle trajectories for those not stopping in response to yellow.]

Solutions

[Excel data file: solutions56.xlsx]

Using Activity #57: Yellow and Red Clearance Intervals (In Practice)

Overview
Students will again be exposed to the Traffic Signal Timing Manual and its treatment of the yellow and red clearance intervals.

Options for Use
- The synthesis and discussion of the questions can be done as part of a group either during class or as homework.

Preparing for the Activity
- Review the relevant sections of the Traffic Signal Timing Manual.

Doing the Activity (Script)
1. Invite them to consider the critical thinking questions and their answers.
2. Ask for answers and discussions for selected questions.

Solution
Critical Thinking Questions and Answers
1. Consider the method that you used in Activity #56 to set the yellow and red clearance intervals, as well as your results. How do they compare with the methods and recommendations described in the Traffic Signal Timing Manual?

2. How does your own driving experience compare with the material from the Traffic Signal Timing Manual relating to the yellow and red clearance intervals?